PEARL MILLET [PENNISETUM AMERICANUM (L.) LEEKE] EMERGENCE, YIELD AND YIELD COMPONENT RESPONSE TO SEED QUALITY AND SOIL TEMPERATURE.

by

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INTRODUCTION

Pearl millet [*Pennisetum americanum* (L.) Leeke] is one of the most important food crops. It is a staple food for millions under the most difficult farming conditions in semi-arid regions of Asia and Africa. It is an important crop where soil fertility is poor and where food supplies depend on the chances of rain. Its performance as a food grain crop in such areas is hampered by the fact that varieties are often characterized by low yields, excessive height, and small seeds that do not offer good emergence. Attention should be focused particularly on developing strains that are higher yielding, disease resistant, and that do not spend too much time in the vegetative stage. Emergence and stand establishment are among the factors that limit yield. The problem involves the quality of seed sources that farmers use, as well as high temperatures and limited moisture at planting time. Although the farmer cannot alter some of these factors, he often tries to select seed from well filled heads with larger seed to enhance emergence and establishment. He assumes that such management practices improve yield.

The objectives of this study were:

1. To test the emergence, yield, and yield-component response of millet seed which exhibited increased size, weight, density, and protein content as a result of management practices applied during seed production.
2. To test the effect of soil temperature on emergence and

yield response of these seed sources.

LITERATURE REVIEW

Pearl millet is the sixth most important cereal crop in the world. Nearly all pearl millet is grown under primitive agricultural conditions(Jere et al., 1977). It has been only within the last twenty years that plant breeders, primarily in India and West Africa, have made attempts at developing improved varieties of pearl millet.

More attention is being placed on millet. This can be seen in current attempts at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India to centralize and expand the world collection of pearl millet. Increased interest is due in part to the recent droughts, which have plagued the Sahel of West Africa, causing many traditional farmers to abandon their lands, and resulting in loss of many local varieties of pearl millet (Jere et al., 1977).

Although pearl millet is an important crop, there are problems in establishing stands for optimum production in areas where millet is grown. This problem has triggered interest in seed quality as a factor that could be altered to improve emergence.

It has been shown that seed size influences the initial development of barley, (*Hordeum vulgare* L.) (Kaufmann and Guitard, 1967). Large seeds produced seedlings with more rapid seedling growth and larger first two leaves than those grown from small seed. Highest grain yield was ob-

tained in barley from larger seed (Demirlicakmak et al.,1963).

Cultural treatments have been found to affect seed size. For example, wide rows were shown to produce larger seed than narrow rows in grain sorghum [Sorghum bicolor (L.) Moench] (Peacock and Ntshole, 1976). In pearl millet, seed size was increased by spikelet removal (Okonkwo, 1983). Physiologically, large seeds are hypothesized to have more carbohydrate reserves for nourishment of the young plant (Austin and Longden, 1967; and Gardner, 1980). Seed weight, seed density, and seed protein content were also found to affect emergence (Okonkwo, 1983). A higher percentage emergence was reported from high density seed than low density seed in pearl millet (Gardner, 1980). A grain yield advantage of 24% in favour of heavy wheat (Triticum aestivum L.) and barley seed was observed (Pinthus and Osher, 1966). Percent germination was higher for the larger and more dense seed classes of sorghum than for the smaller or less dense classes (Maranville and Clegg, 1977). More dense or larger seed fractions also produced more vigorous seedlings. It was concluded that although more dense or larger seed may have a higher percentage germination, this may not increase the number of seedlings emerging in the field or final grain yield. Cotton (Gossypium hirsutum L.) plants grown from well-filled seeds were found to perform better than those grown from partly filled seeds (Turner and Ferguson, 1972). Curtis and McKersie (1984) also reported that seedlings

from larger seed of birdsfoot trefoil (*Lotus corniculatus* L.) grew more rapidly and attained greater height than those from smaller seed.

Seed protein content was found to be increased by nitrogen fertilization (Guthrie et al., 1984) However, percent protein in wheat (Paulsen, 1984) and grain sorghum (Ross et al., 1985) has been found to be negatively correlated with yield. Therefore, selection for seed protein, as the sole criterion, may cause a reduction in yield (Brim and Burton, 1979).

Production of millet seed through spikelet removal, nitrogen application, and visual head selection for seed size at harvest influenced seed size, seed weight, seed density, seed protein, emergence, and yield (Okonkwo, 1983). Head selection and spikelet removal produced seed which consistently showed higher emergence over different environments for several years (Okonkwo, 1983). Yield and yield components were also significantly improved. Nitrogen application increased protein content of seed in 1980 and 1981.

An important question is how seed produced under management practices which improve emergence and have a significant effect on yield would perform under high temperatures.

Temperature has long been recognized as the main environmental determinant of the rate at which plants develop (Ong, 1983). For the first few days after germination,

all seedling growth is within the soil and subject to temperatures of that environment. In particular, the upward growing plumule may encounter temperatures, at and immediately below the soil surface, higher than those at seed depth or in the aerial environment above. It seems probable that extreme temperatures at this stage would inhibit establishment, even when initial germination is excellent (O.S.D.A., 1983). Optimum germination for sorghum was reported at soil temperatures of 21 to 35°C. The lethal temperature for germination ranged from 40 to 48°C (Wilson et al., 1982). These two ranges indicate that there is genetic variation not only in the optimum temperature for germination but also in the temperature at which coleoptiles can survive.

In the semi-arid tropics, performance of pearl millet is determined by water and temperature. These factors are closely linked, and their influences on yield are difficult to separate (Ong, 1983). Low temperature retards anthesis, and reduces rate of dry weight accumulation prior to anthesis. While extremes (21/16 and 33/28°C day/night) reduce main shoot development (Fussel et al., 1980).

Different methods of heating the soil have been reported. A widely used experimental practice for heating soil during cool seasons is mulching with transparent polyethylene (Mahrer et al., 1984). Plastic cover has been used in the field to increase germination and seedling growth of some plants, to increase temperature (Gregory, 1983), to conserve moisture, and to control weeds. Usually for such

purposes, the plastic is placed on the soil surface for only one season (Ong, 1983). A film of transparent polyethylene laid on the soil surface will increase the soil temperature, because, although it is transparent to both solar radiation and to back radiation during the night, its under-surface becomes covered with a film of water droplets which act as a barrier to radiation losses from the soil surface (Mahrer et al., 1984).

Temperatures have also been raised in greenhouses to study the emergence of pearl millet. Charcoal was used to achieve soil temperatures of approximately 55°C, and this high temperature reduced seedling emergence of pearl millet to 4% and of sorghum to 9% (Diouf et al., 1981).

MATERIALS AND METHODS

Seed Sources

The response of millet seed sources to emergence, yield and yield components, and the effect of temperature on emergence and yield response of seed sources were studied in the field, greenhouse, and growth chamber. Seed sources used in the study were all of Senegal Bulk population from the Fort Hays Branch Experiment Station. The following management practices had been applied in production of the seed:

1. Control: No additional management practice was applied in the production of seed.
2. Head selection: Seeds were obtained from heads visually selected for seed size at harvest.
3. Spikelet removal: Spikelets were removed from an area 1.5cm wide from top to base of each panicle as it emerged from the flag leaf.
4. Late thinning: Every other plant was removed at flowering.
5. Nitrogen application: Nitrogen fertilizer was applied 3 weeks after seedling emergence and at boot stage.

Table 1 indicates seed sources used in the studies and when they were produced. The 1980 and 1981 sources were used by Okonkwo (1983).

Table 1. Seed sources used in the 1984 studies.

Seed Source	Year Seed Produced		
	1980	1981	1982
Control	x	x	x
Spikelet Removal	x	x	x
Head Selection		x	x
Late Thinning			x
Nitrogen			x

x Indicates year seed was produced.

These seed sources were tested for seed size, seed weight, seed protein, and seed density by Okonkwo (1983) and Rubottom (1982) (Tables 2,3,4,5). It was found that spikelet removal improved seed size in 1980 compared to control, while in 1981 spikelet removal and head selection improved seed size. Improved seed size was also observed in 1982 on spikelet removal and head selection compared to control. Nitrogen application or late thinning did not increase seed size compared to control (Table 2).

Improved seed weight was also observed with spikelet removal in 1980 compared to control. Spikelet removal and head selection improved seed weight in 1981 and 1982 (Table 3). No improved seed weight was observed for late thinning or nitrogen in 1982.

In 1980 spikelet removal significantly increased protein content (Table 4). In 1981, spikelet removal and head selection increased seed protein content in comparison with control. No differences in protein content were observed among management practices in 1982.

Density was significantly reduced by spikelet removal in 1980. However, in 1981 spikelet removal and head selection improved seed density. In 1982 no density effects were observed (Table 5).

Table 2. Effect of management on seed size.

Seed sources	Year seed produced. 1980[1]	1981[1]	1982[2]
		mm	
Control	2.03 b	2.34 b	2.05 b
Spikelet removal	2.17 a	2.57 a	2.30 a
Head selection	--	2.53 a	2.27 a
Late thinning	--	--	2.03 b
Nitrogen	--	--	1.90 b

* Means with the sameletterwithin a columnare not significantly different

[1] Data from Okonkwo (1983).

[2] Data from Rubottom (1982).

Table 3. Effect of management on seed weight.

Seed sources	Year seed produced. 1980[1]	1981[1]	1982[2]
	---------------g/1000 seed----------		
Control	8.38 b	10.9 b	8.4 b
Spikelet removal	9.18 a	12.8 a	10.4 a
Head selection	--	13.0 a	10.4 a
Late thinning	--	--	8.6 b
Nitrogen	--	--	8.3 b

* Means with the same letter within a column are not significantly different.

[1] Data from Okonkwo (1983).

[2] Data from Rubottom (1982).

Table 4. Effect of management on percent protein.

	Year seed produced.		
Seed sources	1980[1]	1980[1]	1982[2]
Control	10.1 b	12.0 b	11.8 a
Spikelet removal	10.7 a	13.4 a	11.7 a
Head selection	--	12.6 a	11.7 a
Late thinning	--	--	11.8 a
Nitrogen	--	--	11.9 a

* Means with the same letter within a column are not significantly different.

1 Data from Okonkwo (1983).

2 Data from Rubottom (1982).

Table 5. Effect of management on density .

	Year seed produced.		
Seed sources	1980[1]	1981[1]	1982[2]
Control	1.23 a	1.20 b	1.25 a
Spikelet removal	1.22 b	1.26 a	1.25 a
Head selection	--	1.26 a	1.25 a
Late thinning	--	--	1.25 a
Nitrogen	--	--	1.25 a

* Means with the same letter within a column are not significantly different.

1 Data from Okonkwo (1983).

2 Data from Rubottom (1982.)

Germination

A germination test was conducted on the seed sources in 1984 before they were used in the field, the greenhouse, or growth chamber. Twenty-five seeds from each seed source were placed on filter paper in a petri dish and moistened with 0.26% sodium hypochlorite (Chlorox) solution. Petri dishes were placed in a germinator at 30°C for three days when germination counts were taken. The experimental design was a randomized complete block with four replications.

Yield Trials

Field trials were conducted at the Ashland Agronomy farm, Manhattan, and the Sandyland Experimental Field, St. John, Kansas. The objective was to evaluate emergence, yield, and yield-component response of seed sources. The soil type at St. John was a Pratt loamy fine sand (Psammentic Haplustalf, sandy, mixed, thermic) while at Manhattan it was a Haynie fine sandy loam (Mollic Udifluvent, coarse-silty, mixed, mesic). Each source was grown in thinned and unthinned populations in order to separate establishment from other seed quality effects.

The experimental design was a split plot with thinning or no thinning as main plots and seed sources as subplots. Main plots were thinned to a constant population or left unthinned. Each main plot was replicated four times, and each subplot consisted of four rows .75m wide and 7.5m long. Planting was done by a two-row tractor mounted planter. Propazine (2-Chloro-4, 6-bis(isopropyl amino)-s-triazine) was applied preemergence at 2.27kg AI/ha for weed control at Manhattan. Trials were planted on 5 and 6 June 1984, respectively, for Manhattan and St. John. The intended plant population was 48,000 plants per hectare. Extra seeds were planted to compensate for losses due to biological and environmental factors. Stand counts were taken two weeks after planting. Plots should have been thinned to the intended population, but instead they were thinned to 118,000 plants per hectare at St. John and 59,000 per

hectare at Manhattan. The difference in thinning was determined by the level of establishment obtained at each site. Most plots at Manhattan had poor establishment.

To control weeds, plots were cultivated and hand hoed. At maturity, 4.5m of the two center rows of each subplot were harvested. Number of heads per subplot was recorded, and heads were dried and threshed. Grain yield and percent moisture were determined, and grain yield was adjusted to 13% moisture. Seed weight and seeds per head were determined.

Temperature Study

The same 10 seed sources were planted at the Ashland Experimental field (Manhattan) in 1984 to determine the effect of soil temperature on emergence and yield. The soil type was a Haynie fine sandy loam with pH of 6.7, 40.9kg available P/ha, and 1.1% organic matter with 6ppm N (NH4-NO3). A clear plastic soil cover was used in the study to raise soil temperature.

Design was a split plot with soil cover (plastic vs no cover) as main plots and seed sources as subplots. Main plots were 1.5m wide and 54m long. Subplots were 4.5m long and 1.5m wide and were separated by 1.0-m sections. Width of the subplot was determined by the width of the plastic. Plastic width was 0.75m. About 12.5cm on each side was covered with soil to keep the plastic in place. Row spacing within the plots was 0.5m.

The experimental area was disked, rolled, and propazine was applied preemergence at the rate of 2.27 kg A.I./ha. This was followed by laying of the plastic with a plastic laying machine. The experiment was repeated due to unsatisfactorily low soil temperatures after the first study was planted. Soil thermometers were placed 5cm deep in the soil through the plastic, and temperatures were monitored three times a day: 9:00am, 2:00pm and 8:00pm. Seeds were planted through the plastic, using jab planters at the rate of 3 seeds per hill. Three days after emergence, plastic holes were enlarged so that seedlings could grow through the

plastic. Stand counts were taken 10 days after emergence when the plastic was removed. Both rows were harvested. Heads per plot were recorded, dried, and threshed. Grain was weighed, and grain moisture was taken by means of a grain moisture tester. Grain yield per hectare was adjusted to 13% moisture. Seed weight was measured, and number of seeds per head was calculated.

Greenhouse Experiments

Emergence of the same 10 pearl millet seed sources was studied in the greenhouse. The greenhouse study was conducted three times as a split plot, with three replications for experiments one and three, and four replications for experiment two. Temperatures were main plots and seed sources were subplots.

Sandy loam soil used for the study was sterilized, dried, mixed and placed in wooden flats for planting. Seeds were planted 2cm deep in moist soil. One set of flats was covered with a layer of charcoal while the other was covered with a layer of silica sand. Charcoal was used to absorb heat and raise the temperature while white silica sand lowered the temperature. Fifty seeds from each source were planted per row in a wooden flat in the first study. The second and third studies had twenty five seeds per row. There were two rows planted per entry. The first study was planted on 7 August, the second on 4 November, and the third on 29 December, 1984. Soil temperature was monitored, by means of soil thermometers placed 5cm into the soil, at 8:30am, 1:30pm and 7:30pm in the first study; at 8:30am, 2:30pm and 7:30pm for the second study; and at 8:30am, 2:00pm and 7:30pm for the third study. Temperature measurements were taken from 1 to 21 August in the first study, 4 to 12 November in the second study, and 29 December, 1984 to 7 January, 1985 for the third study. Emergence counts were taken on 21 August, 13 November, 1984, and 7

January, 1985 for the three studies.

Growth Chamber Study

Temperatures that had been obtained in the field were rather low. Very high and low temperatures were observed in the greenhouse. These extreme soil temperatures made it desirable to study emergence under a more controlled environment. Seed sources used in the growth chamber were the same as those used in other studies.

Temperatures for the growth chamber study were 43/36 and 32/25^{o}C (day/night), with 12hrs of light. Seeds were planted in vermiculite in cylindrical plastic tubes set in racks placed in trays so that the bottom of the tubes touched water in the bottom of the trays. Three seeds were planted per tube on 7 January 1985.

The experiment was a split plot with temperatures as main plots and seed sources as subplots. These were three replications. Stand counts were taken two weeks after planting and used to calculate percent emergence.

RESULTS AND DISCUSSION.

Germination Determination

Table 6 shows the analysis of variance for percent germination for seed sources used in the field, greenhouse, and growth chamber studies. All management sources, in all three years, had higher germination than the control, indicating that longevity of viability is enhanced by management practices (Table 7).

Germination results from Okonkwo (1983) and Rubottom (1982) (Table 8) show no differences between seed sources in 1980 while in 1981 control seed had better germination than spikelet removal and was equal to seed produced under head selection. In 1982, late thinning and nitrogen application improved germination compared to control and were equal to head selection.

Table 6. Analysis of variance, percent germination, 1984.

Source	Df	Mean Square
Rep	3	17.5
Source	9	303.2**
Error	27	20.1
Total	39	

* Significant at 1%

Table 7. Effect of management on percent germination, 1984.

	Year seed produced		
Seed sources	1980	1981	1982
	%		
Control	78.0 b	78.0 b	81.0 b
Spikelet removal	98.0 a	98.0 a	98.0 a
Head selection	--	98.0 a	94.0 a
Late thinning	--	--	93.0 a
Nitrogen	--	--	97.0 a

* Means with the same letter are not significantly different (LSD 0.05 =7.0, C.V =4.9)

Table 8. Effect of management on percent germination, 1982.

Source	Year seed produced 1980[1]	1981[1]	1982[2]
	%		
control	97.7 a	96.0 a	76.5 b
spikeletremoval	99.7 a	92.5b	85.0 b
head selection		94.5 ab	87.3 ab
late thinning	--	--	91.5 a
nitrogen	--		93.0 a

* Means with the same letterwithin a column are not significantly different.

1 Data from Okonkwo (1983).

2 Data from Rubottom (1982).

Manhattan Yield Trial

Rainfall during the growing season at Manhattan was as follows: June, 28.4 cm (15.23 cm above normal); July 3.35cm (6.55 cm below normal); and August 2.3 cm (5.65 cm below normal).

In this study no source effects were observed on emergence. Emergence was low (mean 29%). Sources were significant at 5% for seed produced per head (Table 9). In 1982 seed, late thinning produced significantly fewer seeds per head compared to control (Table 10). However, there were no significant differences among sources for the seed produced per head in 1980 or 1981.

The thinning x source interaction was not signifiant for any of the variables. Thinned plots produced more seed per head than unthinned plots, probably because of lower plant population (Table 11). However, seeds produced by thinned plots were not significantly heavier.

No yield differences were observed in this study although differences were obtained under normal temperatures at Manhattan in the 1981 study (Okonkwo, 1983). Spikelet removal significantly increased yield (738 kg/ha) and kernel weight over control. Establishment was significantly improved by the same seed source. Although germination percent was high for spikelet removal in 1984, that effect did not translate into higher emergence in the 1984 field trial at Manhattan.

Table 9. Analyses of variance, Manhattan yield trial, 1984.

		Mean Squares					
Source	DF	% Emerg	Plants/Ha x 1000	Head/Ha x 1000	Kg/Ha x 1000	Wt/1000 seed,g	Seed/Head
Rep	3	64.7	258.9	721.0	.170	0.498	140784
Thin	1	25.0	345.2 **	242.6	.001	0.081	1076466*
Error (a)	3	61.3	242.3	435.6	.382	1.124	92035
Source	9	161.3	634.6	370.3	.372	0.458	104476*
Thin*Source	9	106.1	653.8	1144.1	.503	0.172	83588
Error (b)	54	120.2	558.8	1132.2	.688	0.378	93095
Total	79						

* Significant at 5% level.
**Significant at 1% level.

Table 10. Effect of seed source on seed per head, Manhattan yield trial, 1984.

Seed source	seeds/head
1980 seed	
Control	2384 b
Spikelet removal	2670 ab
1981 seed	
Control	2557 ab
Spikelet removal	2600 ab
Head selection	2637 ab
1982 seed	
Control	2790 a
Spikelet removal	2627 ab
Head selection	2541 ab
Late thinning	2448 b
Nitrogen	2537 ab
LSD 0.05	305
C V	11.8

* Means with the same letter are not significantly different.

Table 11. Effect of thinning onyield and yield components, Manhattan yield trial, 1984.

Treatment	Plants/ ha	Heads/ ha	Kg/ha	Wt/1000 seed, g	Seed/ head
Thinned	57221	151141	3513	8.7	2695
Unthinned	98764	162155	3508	8.8	2463
LSD.05	11078	NS	NS	NS	216
C V	19.9	13.3	17.6	12.1	11.8

St. John Yield Trial

Rainfall distribution during the growing season at St. John was as follows: June, 6.1 cm (2.9 cm below normal); July 0.6 cm (6.7 cm below normal); and August, 2.5 cm (3.4 cm below normal). The below normal rainfall at this location was manifested in yield components. Generally, yields were low compared to those at Manhattan.

Seed source differences were obtained for emergence at St. John (Table 12). With 1980 seed sources, no differences were observed, while with 1981 seed, spikelet removal and head selection significantly improved emergence compared to control (Table 13). With 1982 seed, nitrogen application improved emergence compared to control seed, while no differences were observed between control seed and other management sources. Significant differences were also reported for the 1981 nitrogen-application and head selection seed sources by Okonkwo (1983).

Source differences were also observed in heads produced per hectare (Table 12). Only 1981 spikelet removal significantly increased production of heads (Table 13).

The source x thinning interaction was not significant, and no source differences were obtained on other yield components. Thinning contributed to significant differences in heads produced and seed weight (Table 14).

Better emergence was obtained at St. John (57%) than at Manhattan (29%) probably as a result of differences in soil type and greater rainfall at Manhattan which occurred imme-

diately after planting. A greater number of seeds per head was produced at Manhattan than at St. John (Tables 9 and 11). Moisture stress experienced at St. John during the growing season must have contributed to reduced yield and yield components. Generally higher grain yield and a larger number of seeds per head with increased seed weight were obtained at Manhattan.

Table 12. Analyses of variance, St.John yield trial, 1984.

Source	DF	% Emergence	Plants/Ha x 1000	Head/Ha x 1000	KG/Ha x 1000	WT/1000 Seed	Seeds /Head
		Mean Squares					
Rep	3	123.0	14.7	19.3	.49	0.2	575656
Thin	1	0.3	3831.3 **	502.8**	.05	3.4*	334
Error	3	15.5	14.6	19.2	.23	0.3	531825
Source	9	109.2**	20.2	35.9 *	.10	0.4	200423
Src within 1980	(1)	0.3		157.7			
Src within 1981	(2)	274.7**		95.7 **			
Src within 1982	(4)	48.7		132.2**			
Year	(2)	214.5 **		349.7**			
Thin*Src	9	11.3	20.2	22.0	.08	0.5	147742
Error (b)	54	21.0	11.0	17.9	.10	0.3	209451
Total	79						

**Significant at 1%.
* Significant at 5%.

Table 13. Effect of seed source on percent establishment and heads/ha, St. John yield trial, 1984.

Seed source	emergence	head/ha
	%	
1980 seed		
Control	60.2 ab	110854 abc
Spikelet removal	60.5 ab	117132 ab
1981 seed		
Control	52.5 d	100988 c
Spikelet removal	64.3 a	121616 a
Head selection	58.5 bc	104934 bc
1982 seed		
Control	55.5 cd	108343 abc
Spikelet removal	54.4 cd	105114 bc
Head selection	54.3 cd	102782 c
Late thinning	55.6 cd	103858 bc
Nitrogen	60.3 ab	112827 abc
LSD 0.05	4.6	13429
C V	7.9	12.3

* Means with the same letter are not significantly different.

Table 14. Effect of thinning on yield and yield components. St. John yield trial, 1984.

Treatment	Plant/ha	Head/ha	Yield	Wt/1000 Seed	Seed/Head
			Kg/ha	g	
Thinned	114800	100916	673	7.2	936
Unthinned	158568	116773	724	6.7	940
LSD.05	8586	9870	NS	0.4	NS
C V	8.8	12.7	68.4	7.7	77.7

Field temperature studies

Differences in soil temperature were obtained between covered and bare soil in both field studies. A difference of 3.2°C between covered and bare soil was obtained at 9:00am, 8.7°C at 2:00pm and 3.3°C at 8:00pm for the first temperature study (Fig. 1). Significant differences in temperature were also obtained in the second field study (Fig. 2). Temperature at 2:00pm was 42.8 °C for plastic soil cover, and 35.2°C for bare soil. Source differences (Table 15) were observed in emergence for both field studies. In the first study, only head selection in 1981 significantly improved emergence compared to control (Table 16). No difference was obtained between control and spikelet removal in 1980, and no significant differences in emergence occurred among seed sources with 1982 seed. Treatment differences were also obtained in the second field study. Results indicate improved emergence with 1981 spikelet-removal and 1982 head-selection seed (Table 16).

Plants under plastic seemed to have difficulty in emerging through the holes. Emergence problems were also reported with corn grown under plastic (Miller and Bunger 1963). Corn seedlings frequently did not emerge through the perforations and had to be pulled through by hand.

Although more work is probably required, it can be concluded that plastic used as soil cover can raise the soil temperature. However, temperatures were not high enough to simulate soil temperatures in most areas where millet is

grown.

Source differences showed that spikelet removal and head selection improved emergence, though not consistently. Moreover, only seed sources that had improved seed size, weight, protein, and density, as was the case with 1981 seed sources, showed improved emergence. Seed sources with improved seed size and seed weight but low protein and density had low emergence.

Table 15. Analyses of Variance, Field Temperature Studies, 1984.

Source	Df	Mean Squares: Experiment 1. %Emerg	Plants/ha x1,000	Head/ha x1,000	Kg/ha x1,000	Wt/1000 seed,g	Seeds /head	Exp 2. Emerg
Rep	2	66.7	142.8	558.7	.203	0.291	81271	357.4
Cover	1	369.9	792.9	13406.4	.376	0.0002	124024	121.6
Error (a)	2	227.1	486.4	2533.5	1.410	1.198	13385	593.3
Source	9	127.2*	268.8 *	701.8	.540	0.32	194656	204.7*
Src within 1980	(1)	184.5	395.4					307.0
Src within 1981	(2)	361.5**	774.4**					208.0
Src within 1982	(4)	58.0	115.7					238.0*
Year	(2)	476.8**	1017.8**					548.0**
Cover*Trt	9	74.4	180.1	413.5	.180	0.196	25575	88.1
Error (b)	36	60.2	113.4	441.8	.466	0.474	291678	92.6
Total	54							

* Significant at 5% level.
** significant at 1% level.

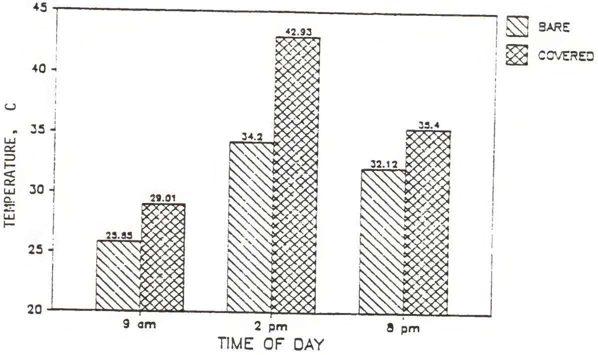

FIG 1. AVERAGE SOIL TEMPERATURES FOR FIRST MILLET STUDY, 29 JUNE TO 15 JULY, 1984.

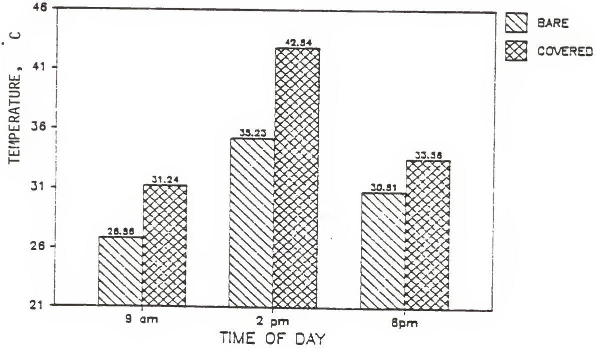

FIG 2. AVERAGE SOIL TEMPERATURES FOR SECOND MILLET STUDY, 23 JULY TO 15 AUG, 1984.

Table 16. Effect of seed source on percent establishment, field temperature studies, 1984.

Seed Source	Establishment Experiment 1	Establishment Experiment 2
	%	%
1980 seed		
Control	22.4 bc	16.9 bc
Spikelet removal	30.2 ab	27.1 ab
1981 seed		
Control	18.8 c	13.1 c
Spikelet removal	26.6 abc	24.8 ab
Head selection	34.3 a	19.4 bc
1982 seed		
Control	24.5 bc	17.8 bc
Spikelet removal	22.1 bc	24.3 ab
Head selection	30.4 ab	32.2 a
Late thinning	25.3 abc	24.0 abc
Nitrogen	27.1 abc	16.3 bc
LSD 0.05	9.1	11.3
C V	29.6	44.5

* Means with the same letter are not significantly different.

Greenhouse Experiments

Significant differences in percent emergence due to temperature and seed sources were obtained in the first and second greenhouse studies (Tables 17 and 18). However, only seed sources caused significant differences in emergence in the third study (Table 17).

Average temperatures in the greenhouse studies are indicated in Table 19. Higher temperatures were obtained under charcoal than under silica sand. Highest temperature at 1:30pm was 45.0^{o}C under charcoal and 37.5^{o}C under silica sand. However, overall temperatures in the second greenhouse study were lower. Temperature at 2:30pm for charcoal was 31.5^{o}C and 24.3 ^{o}C for silica sand. Temperatures in the third study were higher than those in the second study. Highest temperatures were 40.0^{o}C for charcoal and 33.0^{o}C for silica sand at 2:00pm.

Higher temperatures reduced percent emergence significantly in the first greenhouse study (Table 20). Most seedlings under charcoal had the tips of the coleoptiles turned downwards and white in color. Moreover, plants were sparse and less vigorous under charcoal. A significant reduction in emergence of pearl millet under high soil temperatures where charcoal was used was observed Diouf, et al. (1981).

In the second greenhouse study temperatures were lower than in the first and third studies (Table 19). However, temperature effects were significant. Average soil tempera-

tures (Table 13) were in the range that facilitates emergence. No temperature effects were observed in the third study (Table 19).

The source x temperature interaction was not significant in any of the greenhouse studies (Tables 17 and 18). Source differences obtained indicate that with 1980 seed, (Table 21) there was no difference between control and spikelet removal in Experiments 1 and 2. A significant increase of 16% emergence over control was observed for spikelet removal in Experiment 3. With 1981 seed sources, spikelet removal and head selection consistently showed improved emergence over all experiments.

With 1982 seed, emergence for head selection and late thinning in Experiment 1., nitrogen and head selection in Experiment 2, and all management seed sources in experiment 3 was better than the control.

In the previous study (Okonkwo, 1983), the 1980 and 1981 seed sources tested for emergence in the greenhouse in 1982 showed that with 1981 seed sources, head selection improved emergence over the control, while with 1980 seed, no significant differences were obtained among seed sources.

Generally percent establishment was low for the first study where temperatures were highest. However, in all three studies, spikelet removal and head selection showed improved emergence with 1981 seed. With 1982 seed sources, late thinning emerged better than control. In the previous work (Okonkwo, 1983), head selection was found to significantly improve emergence.

Table 17. Analyses of variance, percent emergence, greenhouse studies, 1984.

		Mean Squares	
Source	DF	Exp. 1	Exp. 3
Rep.	2	1923.0	46.0
Temp	1	62402.0*	24.0
Error (a)	2	2509.0	69.0
Source	9	170.0*	429.5**
Src within 1980	(1)	280.0	768.0**
Src within 1981	(2)	266.0*	707.5**
Src within 1982	(4)	145.2	423.5**
Year	(2)	521.2**	1469.5**
Src *Temp	9	88.0	75.0
Error (b)	36	79.6	45.0
Total	59		

* Significant at 5 % level.
**Significant at 1 % level.

Table 18. Analysis of Variace, % Emergence, Greenhouse Study, Exp. 2

Source	DF		Mean Squares
Rep.	3		133.0
Temp	1		192.0*
Error (a)	3		16.7
Src.	9		385.0**
Src within 1980		(1)	110.3
Src within 1981		(2)	652.2**
Src within 1982		(4)	491.4**
Year		(2)	868.9**
Src * Temp	9		90.3
Error (b)	54		55.9
Total	79		

* Significant at 5% level.
** Significant at 1%level.

Table 19. Mean soil temperature for three greenhouse studies.

	Soil cover	
First experiment	Charcoal	Silica sand
(1-21 Aug. 1984)	--------°C -------	
8:30 am	24.3	22.0
1:30 pm	45.0	37.5
7:30 pm	38.7	34.2
Average	36.0	31.2
Second experiment (4-12 Nov. 1984)		
8:30 am	21.0	20.9
2:30 pm	31.5	24.3
7:30 pm	23.8	23.7
Average	25.4	23.0
Third experiment (29 Dec 1984 -7 Jan 1985)		
8:30 am	21.3	19.7
2:00 pm	40.0	33.0
7:30 pm	29.8	26.8
Average	30.4	26.5

Table 20. Effect of temperature on percent emergence, greenhouse studies, 1984.

Temperature	Exp. 1	Exp. 2	Exp. 3
		%	
Low	83.6	77.2	81.2
High	19.1	74.1	79.9
LSD 0.05	55.6	2.9	N.S.
C V	97.5	5.4	10.3

Table 21. Effect of seed source on percent emergence, greenhouse studies, 1984.

Seed source	Emergence Exp 1	Exp 2	Exp 3
	------------------------%	------------------------	------------------------
1980 seed			
Control	49.2 abc	74.0 cde	74.3 cd
Spikelet removal	59.0 a	79.3 bc	90.3 a
1981 seed			
Control	44.2 bc	66.5 e	67.0 de
Spikelet removal	55.2 a	79.8 abc	87.0 ab
Head selection	56.2 a	83.8 ab	84.3 ab
1982 seed			
Control	41.8 c	68.8 e	66.0 e
Spikelet removal	52.0 abc	68.5 e	86.0 ab
Head selection	53.7 ab	71.5 de	82.7 ab
Late thinning	53.5 ab	76.8 bcd	81.3 bc
Nitrogen	49.3 abc	87.3 a	86.3 ab
LSD 0.05	10.5	7.5	7.8
C.V	17.4	9.9	8.3

* Means with the same letter are not significantly different.

Growth Chamber Experiment

In this study seed-source differences were also significant (Table 22). Better emergence was observed in this study than in the greenhouse studies. Neither temperature effects nor source x temperature were significant. However, sources were significant at the 0.01 level. Year that seed was produced was also significant (Table 22).

There were no differences among seed sources produced in 1980. However, with 1981 seed, head selection and spikelet removal significantly improved emergence compared to control. With 1982 seed, improved emergence was obtained from nitrogen application and head selection compared to control. There was no difference between head-selection and spikelet-removal seed produced in 1982 (Table 23).

Table 22. Analysis of variance, growth chamber study, percent emergence, 1984.

Source	DF		Mean Squares
Rep	2		574.0
Temp	1		5453.0
Error (a)	2		1059.0
Source	9		622.0**
Src within 1980		(1)	280.0
Src within 1981		(2)	1516.0**
Src within 1982		(4)	562.0**
Year		(2)	1736.0**
Src*Temp	9		165.0
Error (b)	36		142.3
Total	59		

* Significant at 1% level.

Table 23. Effect of seed sourceson percent emergence, growth chamber study, 1984.

Seed source	Emergence
	%
1980 seed	
Control	64.0 cde
Spikelet removal	73.0 abc
1981 seed	
Control	51.0 e
Spikelet removal	79.7 ab
Head selection	78.0 ab
1982 seed	
Control	57.0 de
Spikelet removal	63.0 cde
Head selection	72.0 abc
Late thinning	66.0 bcd
Nitrogen	82.0 a
LSD 0.05	13.9
C V	17.4

* Means with the same letter are not significantly different.

SUMMARY AND CONCLUSIONS

Management practices imposed on Senegal Bulk population significantly improved seed size, seed weight, seed protein and seed density (Okonkwo, 1983 and Rubottom, 1982), and these sources significantly improved germination and field establishment. Increase in all four characteristics, seed weight, seed size, protein, and density, was obtained only with 1981 seed sources. Nitrogen application did not improve protein content in 1982. Seed weight was improved by spikelet removal and head selection over all years of seed production. Seed weight was not increased by late thinning or nitrogen application. Increased seed size was obtained by spikelet removal and head selection. seed density was increased only in 1981 seed sources. However, both spikelet removal and head selection increased seed density.

Seed sources differed significantly in germination. All management sources showed higher germination than control seed. Control seed declined in germination over years, while seed produced under management practices maintained high germination.

No significant difference was obtained in emergence at Manhattan, but spikelet removal in 1981 and nitrogen application in 1982 improved emergence at St. John. No yield effects were obtained at either location.

The same seed sources were tested under high temperature where plastic was used as soil cover to raise the

temperature. Although increased temperatures were observed where plastic was used, soil temperatures obtained in either field study were not as high as those expected in most areas were millet is grown. Extreme soil temperatures observed in Botswana at planting time are 55+^{o}C (O.S.D.A. 1984).

Source differences in emergence were observed. Only head selection in 1981 increased emergence in the first experiment. Spikelet removal in 1981 and head selection in 1982 improved emergence in the second field experiment. Yield and yield components were not significantly affected by seed source except for plants per hectare from 1981 head selection.

While expected high soil temperatures were not obtained in the field studies, greenhouse studies offered a wide range of soil temperatures. In the first greenhouse study, soil temperatures at 1:30pm under charcoal were 45.0^{o}C while a low of 37.5^{o}C was observed for silica sand.

Increased soil temperatures in the first greenhouse study significantly reduced emergence. Highest emergence was obtained when temperatures were lower, while low emergence occurred under charcoal where temperatures were high. Seed sources showing better emergence than control were spikelet removal and head selection in 1981, late thinning and nitrogen in 1982.

The study has shown that seed sources produced by management practices retain their viability for a longer

time than the control seed. The ability to remain viable much longer may prove helpfull for farmers where drought sometimes does not permit planting of the seed resulting in the seed being kept for several years.

Quality of seed seemed to depend on environment. Seed sources showing improvement in seed size, seed weight, seed density, and seed protein were generally superior to control seed in emergence. Head-selection and spikelet-removal seed usually gave best emergence. However, improved emergence did not result in higher yield. These practices are easy to implement, and may be useful to farmers not able to afford to buy seed every year or where improved seed is not easily obtainable.

In areas where different planting methods are being investigated, it might be helpful to evaluate such seed-production management practices as those used in this study.

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PEARL MILLET [PENNISETUM AMERICANUM (L.) LEEKE] EMERGENCE, YIELD AND YIELD COMPONENT RESPONSE TO SEED QUALITY AND SOIL TEMPERATURE.

by

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AN ABSTRACT OF A MASTERS THESIS

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The major concern for every farmer planting any crop is whether he will get a good stand. Obtaining a good stand may be determined by seed source, enviromental conditions, or a combination of both.

Pearl millet [Pennisetum americanum (L.) Leeke] has poor stand establishment due to small seeds which are hypothesized to be low in carbohydrates. Because of its small seed, the crop is dependent upon favorable seedbed conditions for vigorous early growth.

The study was conducted to test 1. The emergence, yield, and yield-component response of millet seed which exhibited increased size, weight, density, and protein content as a result of management practices applied during seed production. 2. To test the effect of temperature on emergence and yield response of these seed sources.

Seed sources used in the study were Senegal Bulk population, which had been produced under management practices of: 1) Control (1980, 1981 and 1982). 2) Spikelet removal (1980, 1981 and 1982). 3) Head selection (1981 and 1982). 4) Late thinning (1982) and 5) Nitrogen application (1982). It had been found in a previous study that these management practices significantly increased weight, size, protein content, and density of the seed.

Performance of these sources was studied under normal field conditions and under high soil temperatures in the field, greenhouse, and growth chamber. In yield trials at Manhattan and St. John, Kansas, plots were thinned to a

constant population or left unthinned. Soil temperature was increased by plastic cover in the field and by charcoal in the greenhouse.

There was no thinning x source interaction for any of the variables in the yield studies. At Manhattan, seed source differences were observed only with seeds per head, while thinning affected plants/ha and seeds per head.

At St. John, spikelet removal and head selection, in 1981, and nitrogen application, in 1982, improved emergence. Seed from spikelet removal in 1981 produced more heads. However, no increases in yield were obtained with seed produced under those management practices.

In the field temperature studies, no temperature effect or temperature x source interaction was observed for any variable. Source differences in the first study indicated better establishment only with 1981 head selection seed. In the second study, spikelet removal improved emergence with 1981 seed, while no difference was observed between control and head selection.

The soil temperature effect was significant in the first greenhouse study where the highest soil temperature was observed. Temperature effect was also significant in the second greenhouse study although temperatures were not so high. There was no temperature effect in the third greenhouse study.

In the first study, there was increased emergence from spikelet removal and head selection with 1981 seed, while with 1982 seed, head selection and late thinning gave better

emergence. In the second study, head selection and spikelet removal in 1981 produced seed which emerged better than control, while nitrogen-application seed emerged best with the 1982 sources. The third study showed that spikelet removal in 1980 and 1981, head selection in 1981 and all seed sources in 1982 emerged significantly better than control.

No temperature effects were observed in the growth chamber. Source differences indicated improved emergence from head selection and spikelet removal with 1981 seed, and from nitrogen application and head selection with 1982 seed.

Generally, seed produced in 1981, showed more source differences in emergence than those produced in 1980 or 1982. Improved emergence may have been due to improvement in seed quality. Seed size, seed weight, seed protein, and seed density were all significantly improved in only the 1981 seed sources.